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Research Note NC-308

1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.

1984

CHARACTERIZATION AND AIR DRYING OF CHUNKWOOD AND CHIPS

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ABSTRACT.—Chunkwood was found to be composed of a few large particles and many small particles with the large particles constituting almost half the total weight. More than 75 percent of the chunk weight was composed of particles weighing more than 100 grams (ovendry), while 85 percent of the chip weight was composed of particles weighing 3 grams or less. Energy densities ranged from 89,675 Btu/ft^3 for green aspen chips to 162,520 Btu/ft^3 for dried sugar maple chunks.

Chunks and chips were air-dried from July through October in eight covered cribs. For both species tested, the chunks dried faster than the chips to about 20 percent moisture content.

KEY WORDS: Energy, wood, fuel characteristics, moisture content, biomass, fuel preparation.

National and international interest in using biomass and wood for energy continues to grow. The more common forms of industrial wood fuel are hogged mill residues, bark, and sawdust. But mill residues alone cannot meet the projected wood energy demand because they are in limited supply. A current trend is toward harvesting and converting forest biomass to whole-tree fuel chips. Though readily available in large quantities because of the commercial availability of whole-tree chippers, whole-tree chips have certain drawbacks: they require considerable energy to produce, have a low bulk density, and pack closely in storage piles restricting air circulation necessary for natural drying. Also, when burned in industrial combustors, their light weight coupled with high flue velocities tend to produce high solid particulate emissions. Close layering in pile or thin bed combustors restrict the flow of underfire air required for complete combustion.

Scientists at the Forestry Sciences Laboratory at Houghton, Michigan, are searching for new energy-efficient ways to reduce small diameter trees and logging residues into particles suitable for use as wood fuel or as a furnish for flakeboard production or other composite wood materials. Results of this work have been the invention of two machines that produce wood chunks much larger than conventional pulp chips (fig. 1) (Arola *et al.* 1982, Arola *et al.* 1983, Barwise *et al.* 1977, Barwise *et al.* pat. 1984). These chunkwood particles range from finger-size all the way up to discs the full diameter of the small trees or logs being cut.

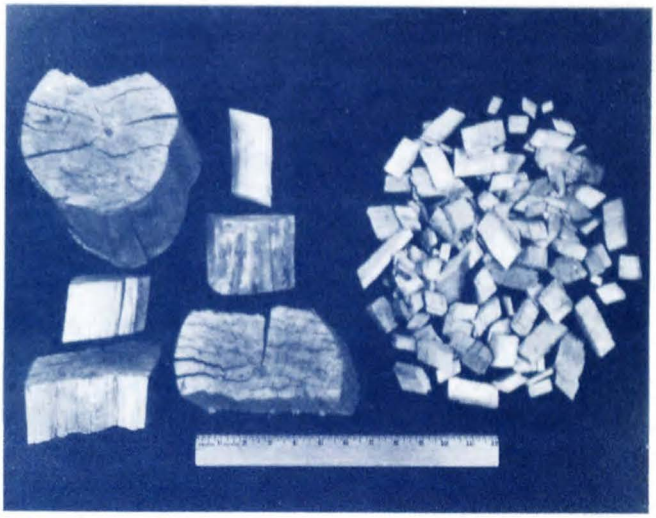

Figure 1.—*Typical shapes and sizes for chunks (left) and chips (right).*

Chunkwood has several advantages over chips for use as fuel. The chunkwood particles are larger and require approximately 67 percent less energy to produce and are higher in bulk density, thus allowing more fuel to be stored or transported in a given space (Arola *et al.* 1983). Also, chunks have larger interparticle voids and appear to dry faster when stored under ambient drying conditions (Sturos *et al.* 1983).

Dried fuel has many benefits over wet fuel: heating values are higher; boiler efficiencies are increased; existing boiler capacity can be increased or new boiler size can be decreased; and stack emissions are reduced (Haygreen 1981).

We carried out a study (1) to document the physical character of chunkwood as a fuel particle, (2) to investigate the air drying characteristics of green chunkwood when stored in outdoor cribs and (3) to compare the drying of conventional pulp chips under the same conditions.

METHODS

Physical Characterization of Chunks

Because chunkwood for fuel is a new concept, sample particles were analyzed for shape, weight, length, width, and height.

The chunk particles were classified into two general cross-sectional shapes: (1) circular sections at least half the diameter of the log being chunked, (2) fragments or pieces less than half the diameter of the log being chunked. The two shape groups were analyzed for distribution by count and weight as well as for average particle weight, length, width, and height (table 1).

Bulk densities, as-fired heating values, and energy densities were calculated for two conditions—green and 20 percent moisture content. Green moisture contents and bulk densities were based on the initial moisture samples, crib volumes, and weights taken for the drying experiment described below (table 2, columns 2 and 3). The dried bulk densities were calculated by mathematically adjusting for reduced moisture and volume. Volume changes were determined by measuring the crib contents both at the beginning and end of the tests. The as-fired heating values were calculated by assuming 6800 Btu/lb (typical for ovendry hardwood) and then mathematically adjusting for moisture content (table 2, column 5). Energy densities were determined by multiplying the as-fired heat values by the corresponding bulk densities (table 2, column 6).

Drying Experiment

The drying portion of this study was designed as a replicated unpaired experiment to test the mean difference in drying rate between chunks and chips.

The basic experiment consisted of four identical 256-cubic foot cribs (fig. 2), two filled with chunks and two filled with an equal volume of chips. The filled cribs were set outdoors in a clear, level spot. This basic four-crib experiment was used for two species—sugar maple and aspen (a total of eight cribs). The cribs were weighed weekly to determine weight (moisture) loss.

Table 1.—*Chunkwood particle shape and size classification*

	Particle cross-sectional shape					
	Circular sections[2]		Fragments[3]		Loose bark and fines[4]	
Characteristic[1]	Maple	Aspen	Maple	Aspen	Maple	Aspen
Percent by count	13	10	87	90	—	—
Percent by weight	49	43	47	51	4	6
Avg. weight grams	725	439	99	56		
(Std. dev.)	91	62	13	6		
Avg. length inches	3.5	3.8	2.8	2.9		
(Std. dev.)	0.9	0.4	1.0	1.1		
Avg. width inches	5.5	5.4	2.9	2.8		
(Std. dev.)	1.5	1.0	1.5	1.6		
Avg. height inches	4.8	4.0	1.1	0.9		
(Std. dev.)	1.7	0.9	0.9	0.8		

[1]All weights and dimensions are for ovendry wood.
[2]Whole discs and pieces with at least half of the log's original cross-section still intact.
[3]Pieces with less than half of the log's original cross-section still intact.
[4]Fines were all particles less than 0.5 grams.

Table 2.—*Bulk density and heating values for chunks and chips*

Column	1	2	3	4	5	6
Species and particle type	Drying time	Moisture content	As-fired bulk density	Assumed ovendry heat value	As-fired heat value	Energy density
	Day	*Percent wet basis*	*Lb/ft³*	*—Btu/lb—*		*Btu/ft³*
Sugar maple						
Chips	0	34	23.5	8,500	5,610	131,840
	26	22	20.9	8,500	6,630	138,570
Chunks	0	34	28.3	8,500	5,610	158,760
	26	20	23.9	8,500	6,800	162,520
Aspen						
Chips	0	50	21.1	8,500	4,250	89,680
	36	27	15.1	8,500	6,210	93,770
Chunks	0	50	23.8	8,500	4,250	101,150
	36	20	15.2	8,500	6,800	103,360

The cribs, 4 feet wide, 8 feet long, and 8 feet high, were constructed from painted lumber and ½-inch mesh hardware cloth screening. The bottoms were made with 5-½-inch wide boards having approximately ½-inch wide ventilation slots between them. Each crib was covered with an 8-foot by 12-foot roof.

The chunks and chips were made from green 4- to 12-inch diameter, 8-foot long, relatively straight delimbed bolts (the bark was left intact). The chunks and chips were generated using the United States Forest Service experimental disc chunker (Arola *et al.* 1983) and a Morbark Model 12 Total Chiparvestor[1], respectively.

During the loading of each crib a 40-pound sample was randomly accumulated and the particles analyzed for size, weight, and moisture content.

The cribs were weighed using portable strain-gaged load cells.

Local weather conditions were documented from data recorded at an official FAA weather station located approximately ¼ mile from the drying site. The mean daily temperature and relative humidity were calculated by averaging four equally spaced readings taken throughout the day (5 am, 11 am, 5 pm, and 11 pm).

[1]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

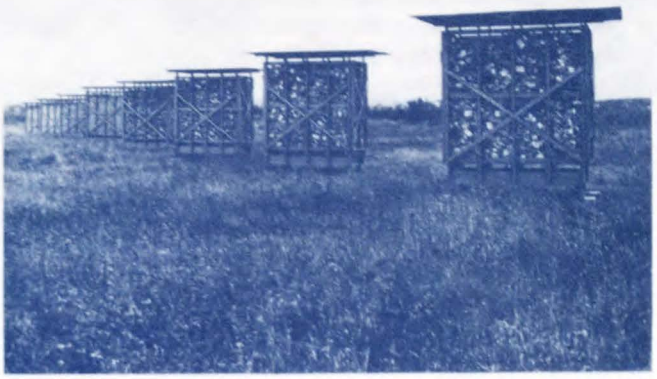

Figure 2.—*Overall crib field setup.*

The initial moisture content of the cribs were assumed to be that of the 40-lb samples taken at the time of loading. The moisture contents were mathematically adjusted to reflect the changing crib weights. Average moisture content and standard deviation curves were generated for both sugar maple and aspen.

RESULTS AND DISCUSSION

Particle Characterization

The chunked material was composed mainly of small disc fragments with a few larger disc sections (table 1). The fragments averaged 99 grams and 56 grams for sugar maple and aspen, respectively, while the larger disc sectons averaged 725 grams and 439 grams, respectively. But for both sugar maple and aspen these large particles constituted almost half of the total sample weight, 49 percent and 43 percent, respectively.

In order to indicate how much larger the chunks were than chips, their particle weight distributions were expressed as percent of total weight rather than count. For sugar maple, 88 percent of the chunk weight was composed of particles weighing more than 100 grams (dry weight), whereas 85 percent of the chip weight was made up of particles weighing 3 grams or less (fig. 3). For aspen, 75 percent of the chunk weight was composed of particles weighing more than 100 grams while 85 percent of the chip weight was made up of particles weighing 2 grams or less (fig. 4).

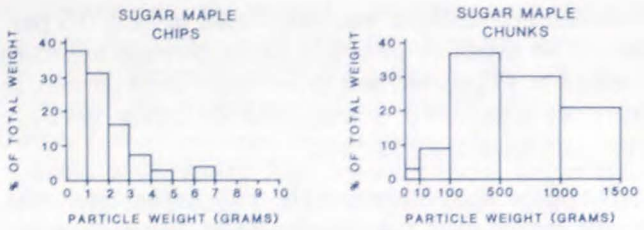

Figure 3.—*Sugar maple particle weight distribution.*

Energy density, Btu/ft³, is a useful term when considering storage bin and boiler sizes. The more dense a fuel, the more energy that can be put into a given space. For sugar maple, the energy density increases 23 percent (from 131,840 Btu/ft³ to 162,520 Btu/ft³) by using dried chunks (20 percent moisture content) rather than green chips (34 percent moisture content) (table 2). Likewise for aspen, the energy density increases 15 percent (from 89,680 Btu/ft³ to 103,360 Btu/ft³) by using dried chunks (20 percent moisture content) rather than green chips (50 percent moisture content).

Weather Conditions

The drying experiments ran from early July through late October 1982. For the sugar maple experiment, which ran 110 days, the temperature averaged 56 degrees with a range of 31 to 75°F (fig. 5). The relative humidity averaged 82 percent and ranged from 58 to 100 percent, and the precipitation totaled 16 inches.

The aspen experiment began 19 days after the sugar maple experiment and ran for 91 days (fig. 6). The temperature averaged 55 degrees with a range of 31 to 74 degrees, the relative humidity averaged 83 percent with a range of 58 to 100 percent, and the precipitation totaled 11.2 inches.

In spite of the roofs on the cribs, some direct rain and roof runoff was blown onto the lower portions of the bins, temporarily raising the moisture levels of

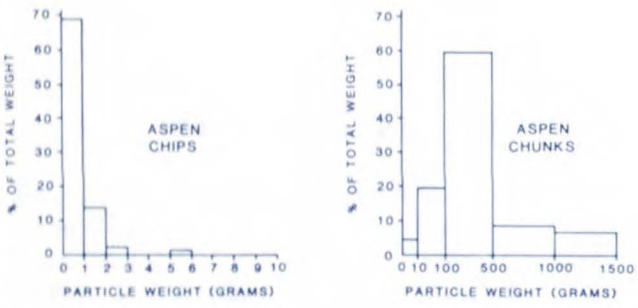

Figure 4.—*Aspen particle weight distribution.*

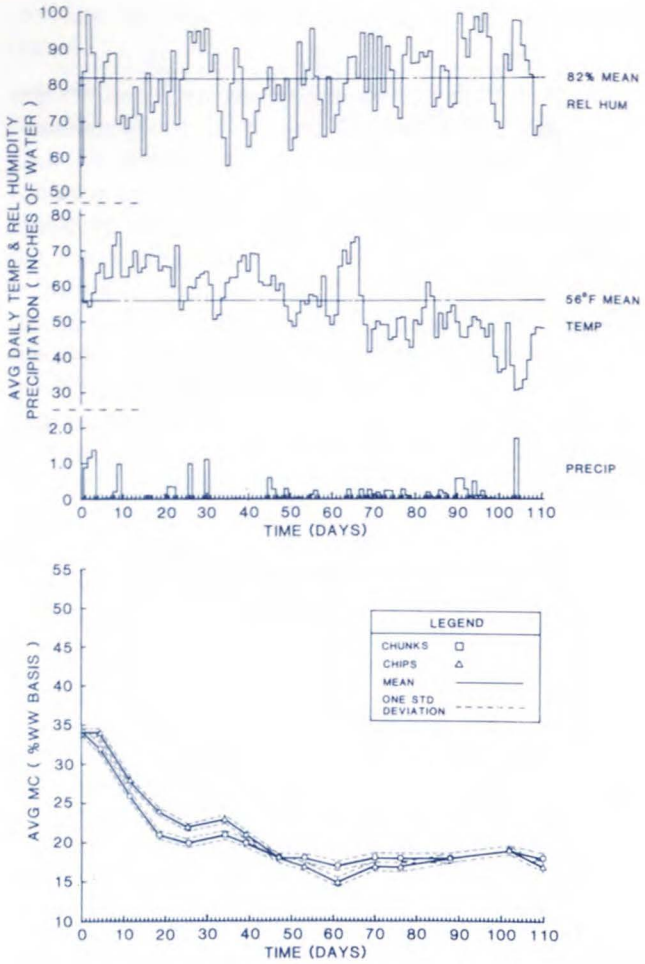

Figure 5.—*Ambient conditions during sugar maple experiment and resultant drying curves.*

particles in the lower portion of the cribs. However, all the cribs were similarly affected, so we felt the effect could be neglected.

Sugar Maple Drying Experiment

The chunks went from an average moisture content of 34 percent down to a minimum of 17 percent in 61 days, and then fluctuated between 18 percent and 19 percent for the remainder of the test (fig. 5). The standard deviation for the variation between replications was calculated to be ± 0.6 percent (represented by the dotted lines on either side of the solid average curves in fig. 5). In comparison, the chips went from 34 percent down to a minimum moisture content of 15 percent in the same 61 days, and then fluctuated between 17 percent and 19 percent for the remainder of the test. The standard deviation was calculated to be ± 0.5 percent.

Even though the chips dried to a slightly lower moisture content than the chunks, the chunks dried

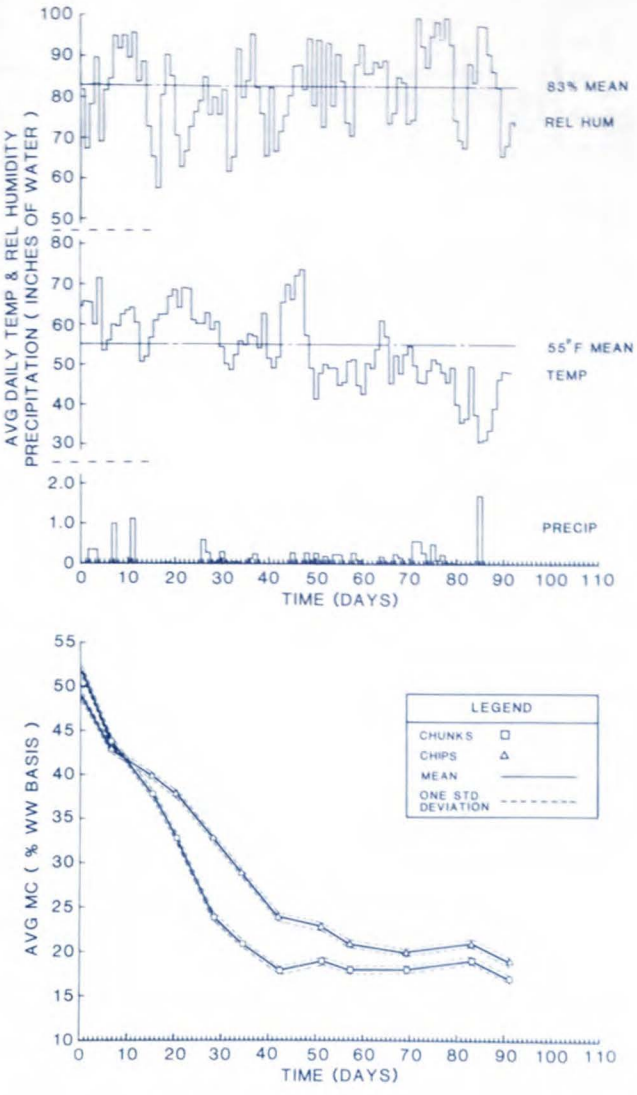

Figure 6.—*Ambient conditions during aspen experiment and resultant drying curves.*

faster than the chips during the first 18 days (fig. 5). At the end of the 18 days, the chunks were at a moisture content of 21 percent and the chips at 24 percent. For the next 43 days the chunk drying rate slowed relative to the chip so that at the end of 61 days, the chips, at 15 percent moisture content, had overtaken the chunks, at 17 percent. From day 61 to the end of the test at 110 days, no further net drying took place; rather, the moisture contents fluctuated with the changes in the weather. In fact, both the chunks and chips gained some moisture—the chips gained slightly more.

Aspen Drying Experiment

For the aspen, the chunks went from an average moisture content of 52 percent down to 17 percent in 91 days of drying (fig. 6). The standard deviation between replications was calculated to be ± 0.5 percent. The aspen chips began at an average moisture content of 49 percent and dried down to 19 percent in 91 days also, with a standard deviation between replications of ± 0.5 percent.

It can be seen more clearly with aspen than with sugar maple that the chunks dried faster than the chips during the earlier part of the drying experiment. Though the chunks and chips began at slightly different levels, the chunks overtook the chips in 9 days and then continued drying at a higher rate until day 28 when the chunks reached 24 percent moisture and the chips 33 percent. From day 28 until the end of the test, the chunk drying rate slowed appreciably with no net drying taking place after 41 days. However, the chips continued to dry so that at the end of the test the chips were at a moisture content of 19 percent and the chunks 17 percent.

CONCLUSIONS

The drying rates of chunks and chips are significantly different. With ambient outdoor crib drying, green chunks will dry faster than chips down to about 20 percent moisture content. As the drying continues beyond this point, the chunks begin to lose their lower moisture advantage over chips with both eventually reaching the same equilibrium moisture content. Chunkwood offers a promising alternative to chips as a fuel particle. It has a higher energy density and dries faster under ambient conditions. However, to capitalize on the advantage of faster initial drying, the time in storage, storage capacity, and the rate of use would have to be carefully coordinated.

Future studies should investigate combustion characteristics of chunkwood using various energy convertors, differences in drying of whole-tree chunks and chips, differences in microbial growth during storage of chunks and chips, storage bin design to enhance drying, and drying characteristics of uncovered outdoor chunk piles.

LITERATURE CITED

Arola, Rodger A.; Radcliffe, Robert C.; Winsauer, Sharon A.; Matson, Edsel D. A new machine for producing chunkwood. Res. Pap. NC-211. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1982. 8 p.

Arola, Rodger A.; Winsauer, Sharon A.; Radcliffe, Robert C. Chunkwood production: a new concept! For. Prod. J. 33(7/8): 43-51; 1983.

Barwise, Robert D.; Arola, Rodger A.; Erickson, John R. Helical head comminuting shear. U.S. Patent 4,053,004. October 11, 1977.

Barwise, Robert D.; Arola, Rodger A.; Matson, Edsel D. Involuted disc slicer. U.S. Patent 4,431,039. February 14, 1984.

Haygreen, John G. Potential for compression drying of green wood chips. For. Prod. J. 31(8): 43-54; 1981.

Sturos, Joseph B.; Coyer, Lynne A.; Arola, Rodger A. Air drying of chunkwood and chips. Res. Note NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 4 p.

*U.S. GPO 766-470/1519